# Chemical Analysis of 1794 & 1795 U. S. Silver Coins – Phase 1 Data

**David Finkelstein and Christopher Pilliod – September, 2018**

## 1.0 Overview

The single most important Mint related legislation in our nation's history was the Mint and Coinage Act of April 2, 1792. In addition to establishing the first Mint of the United States, one of the key aspects of this law was the requirement that the silver coinage was to contain 1485 parts of fine silver and 179 parts alloy (copper). This equated to 89.24278% or 89.24+% silver, and 10.75722% or 10.76-% copper.

Multiple documents stored within the National Archives and Records Administration (NARA) and the Library of Congress indicate that under the leadership of Mint Directors David Rittenhouse and Henry William de Saussure, some or all of the 1794, and most or all of the 1795 dated silver coins were produced to a 90% silver and 10% copper standard. Then, beginning in November, 1795, under the leadership of its third Director, Elias Boudinot, the Mint reverted to the 89.24+% silver and 10.76-% copper standard.

This document provides only the XRF and ICP-AES data. It does not include the history, overview and goals of this research project, images and discussions of documents from the NARA and the Library of Congress related to this project, the analyses of the data, and the preliminary conclusions.

Note that this document uses the terms *trace* and *residual*. *Trace* refers to a relatively low amount and *residual* refers to a relatively high amount.

## 2.0 X-ray Fluorescence Surface Results – January, 2017

In January, 2017, Chris Pilliod performed X-ray Fluorescence (XRF) analysis on the surfaces of two circulated 1795 Half Dollars. Although the Half Dollars were approximately 2,150 microns thick, the XRF analysis could only penetrate 6 to 10 microns. Three different areas of the surface of each coin were analyzed, each identifying above standard silver content (94% - 97%), below standard copper content (2% - 4%), and silicon on the surface of each coin. See Table 1.

Note that the 1795 Half Dollars in Table 1 are listed in emission order sequence. The 1795 Overton 122 (or O-122) die marriage was struck before the 1795 O-105 die marriage.

| What | Area | Silver % | Copper % | Silicon % |
|---|---|---|---|---|
| 1795 O-122 | 1 | 97.43 | 2.09 | 0.48 |
| | 2 | 97.07 | 2.42 | 0.51 |
| | 3 | 96.36 | 3.11 | 0.53 |
| 1795 O-105 | 1 | 95.49 | 3.87 | 0.64 |
| | 2 | 94.45 | 3.92 | 0.63 |
| | 3 | 95.76 | 3.61 | 0.63 |

**Table 1 – XRF Silver Coin Surface Analysis (January, 2017)**

## 3.0 X-ray Fluorescence Subsurface Results – January, 2017

The 1795 O-122 and 1795 O-105 Half Dollars were sliced into three pieces with a diamond cutter to minimize kerf loss [the loss associated with the cutting tool]. The center piece of each Half Dollar was ground, removing approximately 10% of the metals from each side and edge, and polished to insure uniform removal. The target of 10% removal by weight was to comfortably insure that no surface effect would interfere with the results.

In January, 2017, Chris Pilliod performed XRF analysis of three different areas on the subsurface of each of the two 1795 Half Dollars. The results identified 90% - 91% silver content, 9% -10% copper content, no silicon, and no other trace elements. See Table 2.

| What | Area | Silver % | Copper % |
|---|---|---|---|
| 1795 O-122 | 1 | 90.07 | 9.93 |
| | 2 | 90.38 | 9.62 |
| | 3 | 90.78 | 9.22 |
| 1795 O-105 | 1 | 90.04 | 9.96 |
| | 2 | 90.45 | 9.55 |
| | 3 | 91.02 | 8.98 |

**Table 2 – XRF Silver Coin Subsurface Analysis (January, 2017)**

## 4.0 ICP-AES Results – February 2017

In February, 2017, Chris Pilliod sent the ground and polished center sections of the 1795 O-122 and 1795 O-105 Half Dollars to an independent laboratory. Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) analysis was performed on two different 0.5 gram samples from each coin. See Table 3.

Each sample was diluted in Nitric Acid; a highly corrosive acid. A plasma torch vaporized fine droplets of the sample at a temperature of approximately 12,000 degrees Fahrenheit. The atoms of the sample generated wavelengths that were measured by an array of semiconductor photodetectors. Note that for some elements, ICP-AES is accurate to parts per trillion.

| What | Sample | Silver % | Copper % | Gold % | Lead % | Other % |
|---|---|---|---|---|---|---|
| 1795-122 | 1 | 90.00 | 9.20 | 0.38 | 0.35 | 0.07 |
| | 2 | 90.02 | 9.18 | 0.38 | 0.35 | 0.07 |
| | | | | | | |
| 1795-105 | 1 | 90.40 | 9.16 | 0.20 | 0.22 | 0.02 |
| | 2 | 90.46 | 9.10 | 0.20 | 0.22 | 0.02 |

**Table 3 – ICP-AES Silver Coin Subsurface Analysis (February, 2017)**

## 5.0 ICP-AES Results – Copper Coins - August, 2018

In July, 2018, Chris Pilliod sent the ground and polished center sections of one 1794 Large Cent and one 1795 Half Cent to an independent laboratory for ICP-AES analysis. The results identified 98% - 99% copper, with residual levels of lead, and trace amounts of arsenic, bismuth and silver in each coin. See Table 4.

| What | Sample | Copper % | Lead % | Silver % | Gold % | Arsenic % | Bismuth % |
|---|---|---|---|---|---|---|---|
| 1794 Cent | 1 | 98.20 | 1.62 | 0.01 | 0.00 | 0.08 | < 0.01 |
| | 2 | 98.20 | 1.62 | 0.01 | 0.00 | 0.08 | < 0.01 |
| | | | | | | | |
| 1795 ½ Cent | 1 | 99.00 | 0.36 | 0.08 | 0.00 | 0.37 | 0.15 |
| | 2 | 98.99 | 0.36 | 0.08 | 0.00 | 0.37 | 0.15 |

**Table 4 – ICP-AES Copper Coin Subsurface Analysis (August, 2018)**

## 6.0 ICP-AES Results – Silver Coins - August, 2018

In July, 2018, Chris Pilliod sent the ground and polished center sections of one 1794 O-105 Half Dollar and five 1795 Half Dollars (Overton die marriages O-117, O-115, O-116, O-109 and O-110) to an independent laboratory for ICP-AES analysis. See Table 5. The 1794 O-105 Half Dollar was donated by the Terry Brand Estate via Heritage Auctions.

Note that the 1795 Half Dollars in Table 5 are arranged by emission order sequence. Also note that Table 5 includes the results for the 1795 O-122 and 1795 O-105 Half Dollars that were analyzed via ICP-AES in February, 2017.

Chris Pilliod also sent the ground and polished center sections of the subsurface of one 1806 Quarter, one 1807 Quarter, one 1807 Half Dollar, and one 1855-O Half Dollar to an independent laboratory for ICP-AES analysis. See Table 6.

For the purpose of this preliminary analysis, the assumption is being made that five eighths or 62 ½ % of the lead in the silver coins was a residual of the silver refining, and three eighths or 37 ½ % of the lead in the silver coins originated from the copper alloy. Refer to Table 7 for the adjusted percentages of the silver and copper based on these assumptions.

| What | Sample | Silver % | Copper % | Gold % | Lead % | Other % |
|---|---|---|---|---|---|---|
| 1794 O-105 | 1 | 88.67 | 11.01 | 0.12 | 0.17 | 0.03 |
| | 2 | 88.75 | 10.81 | 0.12 | 0.17 | 0.03 |
| | 3 | 88.43 | 11.14 | 0.12 | 0.17 | 0.02 |
| | 4 | 88.73 | 10.95 | 0.12 | 0.18 | 0.02 |
| | | | | | | |
| 1795 O-117 | 1 | 88.96 | 10.23 | 0.36 | 0.43 | 0.02 |
| | 2 | 88.48 | 10.71 | 0.34 | 0.45 | 0.02 |
| | | | | | | |
| 1795 O-122 | 1 | 90.00 | 9.20 | 0.38 | 0.35 | 0.07 |
| | 2 | 90.02 | 9.18 | 0.38 | 0.35 | 0.07 |
| | | | | | | |
| 1795 O-115 | 1 | 89.24 | 10.34 | 0.20 | 0.19 | 0.03 |
| | 2 | 89.29 | 10.30 | 0.20 | 0.18 | 0.03 |
| | | | | | | |
| 1795 O-116 | 1 | 89.83 | 9.87 | 0.20 | 0.09 | 0.01 |
| | 2 | 89.87 | 9.82 | 0.20 | 0.10 | 0.01 |
| | | | | | | |
| 1795 O-109 | 1 | 89.79 | 9.83 | 0.21 | 0.14 | 0.03 |
| | 2 | 90.20 | 9.45 | 0.20 | 0.12 | 0.03 |
| | | | | | | |
| 1795 O-110 | 1 | 90.97 | 8.70 | 0.16 | 0.14 | 0.03 |
| | 2 | 91.31 | 8.35 | 0.16 | 0.14 | 0.04 |
| | | | | | | |
| 1795 O-105 | 1 | 90.40 | 9.16 | 0.20 | 0.22 | 0.02 |
| | 2 | 90.46 | 9.10 | 0.20 | 0.22 | 0.02 |

**Table 5 – ICP-AES Silver Coin Subsurface Analysis (August, 2018)**

| What | Sample | Silver % | Copper % | Gold % | Lead % | Other % |
|---|---|---|---|---|---|---|
| 1806 Quarter | 1 | 88.27 | 10.75 | 0.85 | 0.10 | 0.03 |
| | 2 | 88.35 | 10.69 | 0.82 | 0.10 | 0.04 |
| | | | | | | |
| 1807 Quarter | 1 | 88.40 | 10.68 | 0.84 | 0.05 | 0.03 |
| | 2 | 87.86 | 11.17 | 0.85 | 0.11 | 0.01 |
| | | | | | | |
| 1807 Half Dollar | 1 | 87.87 | 11.24 | 0.80 | 0.08 | 0.01 |
| | 2 | 87.78 | 11.24 | 0.83 | 0.11 | 0.04 |
| | | | | | | |
| 1855-O Half Dollar | 1 | 88.64 | 10.63 | 0.47 | 0.21 | 0.05 |
| | 2 | 88.95 | 10.22 | 0.48 | 0.28 | 0.07 |

**Table 6 – ICP-AES Silver Coin Subsurface Analysis (August, 2018)**

| What | Sample | Silver % + Gold % + 0.625 * Lead % | Copper % + 0.375 * Lead % + Other Trace % |
|---|---|---|---|
| 1794 O-105 | 1 | 88.90 | 11.10 |
| | 2 | 88.98 | 10.90 |
| | 3 | 88.66 | 11.22 |
| | 4 | 88.96 | 11.04 |
| | | | |
| 1795 O-117 | 1 | 89.59 | 10.41 |
| | 2 | 89.10 | 10.90 |
| | | | |
| 1795 O-122 | 1 | 90.60 | 9.40 |
| | 2 | 90.62 | 9.38 |
| | | | |
| 1795 O-115 | 1 | 89.56 | 10.44 |
| | 2 | 89.60 | 10.40 |
| | | | |
| 1795 O-116 | 1 | 90.09 | 9.91 |
| | 2 | 90.13 | 9.87 |
| | | | |
| 1795 O-109 | 1 | 90.09 | 9.91 |
| | 2 | 90.48 | 9.53 |
| | | | |
| 1795 O-110 | 1 | 91.22 | 8.78 |
| | 2 | 91.56 | 8.44 |
| | | | |
| 1795 O-105 | 1 | 90.74 | 9.26 |
| | 2 | 90.80 | 9.20 |

**Table 7 – Adjusted ICP-AES Silver Coin Subsurface Analysis (Aug, 2018)**